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# ASSESSMENTS OF FUELS FOR MILITARY USE PREPARATION AND DISTRIBUTION OF SYNTHETIC FUEL BLENDS

## INTERIM REPORT
## TFLRF No. 432

by
**Edwin A. Frame**
**Ruben Alvarez**

**U.S. Army TARDEC Fuels and Lubricants Research Facility**
**Southwest Research Institute® (SwRI®)**
**San Antonio, TX**

**for**
**Patsy Muzzell**
**U.S. Army TARDEC**
**Force Projection Technologies**
**Warren, Michigan**

**Contract No. W56HZV-09-C-0100 (WD0004–Tasks 1, 20, 21, 26, & 27)**



**January 2013**

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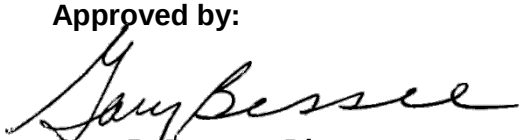

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Fuel blends of 50% synthetic fuel and 50% JP-8 were prepared, analyzed and distributed for testing by TFLRF.

**15. SUBJECT TERMS**
Synthetic Fuel Blend, Synthetic Paraffinic Kerosene (SPK), Hydrotreated Renewable Jet Fuel, JP-8

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# EXECUTIVE SUMMARY

TFLRF prepared, analyzed and distributed blends of synthetic fuel with JP-8. The size of the blends ranged from several hundred to over ten thousand gallons. The fuel blends were used by TARDEC in the evaluation of future fuels for military use. Ten thousand gallons of synthetic fuel blend consisting of 50%v synthetic JP-5 (HRJ-5) and 50%v JP-8 were prepared and delivered to Camp Grayling, MI for use in field exercises conducted by the Michigan National Guard during the summer of 2012.

# FOREWORD/ACKNOWLEDGMENTS

The U.S. Army TARDEC Fuel and Lubricants Research Facility (TFLRF) located at Southwest Research Institute (SwRI), San Antonio, Texas, performed this work during the period April 2009 through January 31, 2013 under Contract No. W56HZV-09-C-0100. The U.S. Army Tank Automotive RD&E Center, Force Projection Technologies, Warren, Michigan administered the project. Mr. Eric Sattler served as the TARDEC contracting officer's technical representative. Ms. Patsy Muzzell of TARDEC served as project technical monitor.

The authors would like to acknowledge the contribution of the TFLRF technical support staff along with the administrative and report-processing support provided by Dianna Barrera.

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| %v | Percent by Volume |
| ˚C | Degrees Centigrade |
| ˚F | Degrees Fahrenheit |
| ASTM | American Society for Testing and Materials |
| BOCLE | Ball-On Cylinder Lubricity Evaluator |
| cSt | Centistokes |
| DCN | Derived Cetane Number |
| HFRR | High Frequency Reciprocating Test Rig |
| HRJ | Hydrotreated Renewable Jet Fuel |
| JP-8 | Jet Propulsion Fuel 8 |
| kg | kilogram |
| lbs | Pounds |
| mL | milliliter |
| ppm | parts per million |
| FT-SPK | Fischer-Tropsch Synthetic Paraffinic Kerosene |
| SLBOCLE | Scuffing Load Ball-On Cylinder Lubricity Evaluator |
| SwRI® | Southwest Research Institute® |
| TARDEC | Tank Automotive Research, Development and Engineering Center |
| TFLRF | TARDEC Fuels and Lubricants Research Facility |
| ULSD | Ultra-Low Sulfur Diesel |
| DLA | Defense Logistics Agency |
| CoA | Certificate of Analysis |
| WPAFB | Wright Patterson Air Force Base |

# 1.0 BACKGROUND AND OBJECTIVE

Fuel supplies are evolving as more highly-processed petroleum fuels, unconventional fuels, and non-petroleum fuels are increasingly making their way into the marketplace worldwide. Some of this evolution began several years ago when, for instance, environmental legislation in the U.S. mandated cleaner tailpipe emissions and as a result, the need for more highly-processed fuels, i.e., lower sulfur and lower aromatic content fuels such as California Air Resources Board (CARB) Diesel and Ultra-Low Sulfur Diesel (ULSD) fuels. The move towards developing and using non-petroleum fuels, such as biodiesel, renewable diesel/jet fuel, or Fischer-Tropsch fuels, is occurring in many countries as spurred by high volatility in the oil market, especially since 2006. In addition, much of the impetus behind transitioning to alternative fuels is tied to the desire of nations to better secure their energy supply by reducing dependence on foreign sources of oil through conversion of in-country energy resources such as tar sands, shale oil, coal, natural gas, biomass/waste streams (renewable) into transportation fuels. Furthermore, power and mobility systems are also evolving that might require non-traditional fuels/energy carriers as sources of energy, e.g., hydrogen for fuel cells. As these changes in the supply of fuels occurs around the world, and also in the fuels specified for future engines/equipment designs, the U.S. Military needs to understand the extent and nature of these changes and the implications regarding current and future military use. There will be some subtle and not so subtle changes in fuel compositions and associated physicochemical properties that can impact engine performance and durability, or compatibility with current (petroleum) fuels and the fuel distribution systems found in engines/vehicles such as fuel pumps, injectors, and high pressure common rail systems, or in fuel storage, distribution, or handling equipment. The U.S. Army is investigating assessments of the changing worldwide fuels supply with a focus on kerosene and diesel boiling range fuels, and of the impacts that varying fuel properties may have on current and future military equipment and systems.

# 2.0 APPROACH

As part of the U. S. Army investigation of future fuels, the U.S. Army TARDEC Fuels and Lubricants Research Facility (TFLRF) has prepared, and shipped fuel blends for engine and component testing. The target fuel blend was 50%v synthetic fuel: 50%v JP-8. Some minor adjustment to this blend ratio was allowed to achieve a blend density of at least 0.773 kg/L and a blend aromatic content of at least 6%v. Each blend contained between 48 to 50%v synthetic fuel.

# 3.0 RESULTS

## 3.1 FUEL BLENDS PREPARED

A listing of the fuel blends prepared and shipped is presented in Table 1.

**Table 1. Fuel Blends Prepared by TFLRF**

| Date | Fuel Blend Code | Fuel Blend Description | Gallons | Shipped To | Density of Blend, kKg/L | KVIS, 40°C, cSt | BOCLE Wear Scar, mm | Aromatics %v |
|---|---|---|---|---|---|---|---|---|
| Jun 09 | AF 6934 | JP-8/SPK | 6,200 | TARDEC | 0.7809 | 1.12 | 0.55 | 10.5 |
| Jun 10 | AF 7117 | JP-8/SPK | 7,000 | TARDEC | 0.7741 | 1.23 | 0.55 | 9.3 |
| Jul 10 | AF 7117 | JP-8/SPK | 2,600 | TARDEC | 0.7741 | 1.23 | 0.55 | 9.3 |
| Oct 10 | AF 7117 | JP-8/SPK | 165 | TARDEC | 0.7741 | 1.23 | 0.55 | 9.3 |
| Dec 10 | AF 7744 | JP-8/HRJ-8 | 4,400 | TARDEC | 0.7823 | 1.5 | 0.47 | 10.7 |
| July 11 | CL11-2644 | JP-8/HRJ-8 | 7,000 | TARDEC | 0.7752 | 1.4 | 0.61 | 11.4 |
| Feb 12 | CL12-3384 | JP-8/HRJ-8 | 6,700 | TARDEC | 0.7787 | 1.34 | 0.47 | 8 |
| Jun 12 | AF 8252 | JP-8/HRJ-8 | 6,500 | TARDEC | 0.7715 | 1.3 | 0.53 | 6 |
| Jun 12 | AF 8259 | JP-8/HRJ-5 | 5,000 | Grayling | 0.7736 | 1.4 | 0.56 | 6 |
| Jun 12 | AF 8261 | JP-8/HRJ-5 | 5,000 | Grayling | 0.7736 | 1.4 | 0.56 | 6 |

## 3.2 FT-SPK BLENDS

A 6,200 gallon blend of 50/50%v FT- SPK and JP-8 (Jet A+ additives) was prepared and designated AF-6934. The FT-SPK was received from the U. S. Air Force. The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. The fuel blend properties for AF-6934 are presented in Table 2. This blend was shipped to TARDEC in June 2009.

**Table 2. Properties of Fuel Blend AF-6934**

| Analysis of Sythetic Fuel Blend Property | Test Method | AF-6934 |
|---|---|---|
| Density, 15°C (g/mL) | D4052 | 0.7809 |
| Kinematic Viscosity, 40°C (cSt) | D445 | 1.12 |
| Sulfur (wt%) | D2622 | 0.0069 |
| Hydrocarbons by FIA | D1319 | |
| Aromatic (vol%) | | 10.5 |
| Olefin (vol%) | | 1 |
| Saturates (vol%) | | 88.5 |
| Heat of Combustion | D240 | |
| GROSS (BTU/lb) | | 19967 |
| NET (BTU/lb) | | 18645 |
| Flash Point (°F) | D93 | 124 |
| (°C) | | 51 |
| SLBOCLE (g) | D6078 | 2200 |
| BOCLE (mm) | D5001 | 0.55 |
| HFRR (µm) | D6079 | 631 |
| Distillation (°C) | D86 | |
| IBP | | 161.4 |
| 10 | | 171 |
| 20 | | 174.4 |
| 50 | | 187.1 |
| 90 | | 223.1 |
| FBP | | 245.4 |
| Cetane Number | D613 | 49.9 |
| Calculated Cetane | D976 | 46.6 |
| Derived Cetane Number | D6890 | 48.2 |
| Particulate Contamination | D5452 | |
| Total Volume (L) | | 1 |
| Total Contamination (mg/L) | | <0.1 |
| Water Content (ppm) | D6304 | 69 |
| Carbon (mass%) | D5291 | 85.46 |
| Hydrogen (mass%) | D5291 | 14.49 |

A 17,000-gallon blend of 50%v FT-SPK and 50%v JP-8 was prepared and designated AF-7117. The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. Properties of the fuel blend are shown in Table 3 below. The density at 15°C was 0.7741, with 9.3% aromatics, and a KVIS at 40°C of 1.23 cSt.

**Table 3. Properties of Fuel Blend AF-7117**

| Property | Test Method | AF-7117 |
|---|---|---|
| Density, 15°C (g/mL) | D4052 | 0.7741 |
| Kinematic Viscosity, 40°C (cSt) | D445 | 1.23 |
| Sulfur (wt%) | D2622 | 0.00044 |
| Hydrocarbons by FIA | D1319 | |
| Aromatic (vol%) | | 9.3 |
| Olefin (vol%) | | 1 |
| Saturates (vol%) | | 89.7 |
| Heat of Combustion | D240 | |
| GROSS (BTU/lb) | | 20,005 |
| NET (BTU/lb) | | 18,695 |
| Flash Point (°F) | D93 | 119.3 |
| (°C) | | 48.5 |
| SLBOCLE (g) | D6078 | 1900 |
| BOCLE (mm) | D5001 | 0.55 |
| HFRR (µm) | D6079 | 684 |
| Distillation (°C) | D86 | |
| IBP | | 161.4 |
| 10 | | 169.9 |
| 20 | | 172.8 |
| 50 | | 184.9 |
| 90 | | 219.1 |
| FBP | | 239 |
| Cetane Number | D613 | 48.8 |
| Calculated Cetane | D976 | 46.6 |
| Derived Cetane | D6890 | 48.8 |
| Particulate Contamination | D5452 | |
| Total Volume (L) | | 1 |
| Total Contamination (mg/L) | | 2.4 |
| Water Content (ppm) | D6304 | 69 |
| Carbon | D5291 | 85.35 |
| Hydrogen | D5291 | 14.35 |

TFLRF delivered 7,000 gallons of fuel blend AF-7117 to TARDEC during June 2010, and an additional 2,600 gallons were delivered to TARDEC during July 2010. Three (3) 55 gallon drums of AF-7117 fuel blend were supplied to the TARDEC propulsion group during October 2010. The balance of the fuel blend was used for testing at TFLRF.

### 3.3 HEFA-SPK (HRJ) BLENDS

TFLRF prepared several 50/50 % blends of hydrotreated renewable jet fuel (HRJ) and JP-8. Both HRJ-8 and HRJ-5 were received from DLA Energy. The HRJ-8 was sourced from Centuri Technologies LP. Three separate shipments of HRJ-8 fuel (18,450 gallons) were received from Centauri Technologies LP during October 4, 6, and 7, 2010. The HRJ-8 fuel was unloaded into Tank 125. Samples were obtained from each tanker prior to unloading into Tank 125. Selected analyses were requested from each sample obtained from the tankers and results were compared with the Certificates of Analysis provided with each shipment. The analyses are presented in Table 4. No anomalies were noted in the results.

A second shipment of HRJ-8 was received from Centauri Technologies, LP. Three separate shipments totaling 16,382 gallons were delivered to TFLRF on January 25, 26, and 27, 2011. The product was initially stored in a rented 12,000 gallon portable tank and a 6,000 gallon above ground tank. The separate shipments were from the same batch number and were segregated from the previous deliveries of HRJ-8 as was requested by TARDEC. The product was transferred from the portable storage tank to a permanent storage tank after completion of repairs required for standards compliance. Samples were obtained from each separate delivery tanker and selected analyses were performed on all samples to compare results of the Certificate of Analysis (COA), provided by Centauri Technologies, LP against results obtained by TFLRF laboratory. Results of Comparison analyses are presented in Table 5, and no anomalies found in any of the samples analyzed.

HRJ-8 and JP-8 fuel were blended at 50%:50% volumetric ratio and the blend attained a density value of 0.782 kg/L and an aromatic content of 10.5 % v. The blend met TARDEC's requirement of no less than 0.773 kg/L and an aromatic content of no less than 6.5 % v. The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. The 4,400 gallons of blended fuel were shipped to TARDEC in December 2010. Complete fuel analyses of the blend and both HRJ-8 shipments are presented in Table 6.

**Table 4. Comparison of Analyses Results of 1st Shipment of HRJ-8 CAF- 7667**

| HRJ-8 CAF-7667 Comparison Analyses (1st Shipment, 18,450 gallons, 4,6,& 7 October 2010) | | | | | | |
|---|---|---|---|---|---|---|
| **Properties** | **Results, COA Tanker 1** | **Results, TFLRF Lab** | **Results, COA Tanker 2** | **Results, TFLRF Lab** | **Results, COA Tanker 3** | **Results, TFLRF Lab** |
| ASTM D86 Distillation | | | | | | |
| IPB (°C) | n/d | 143.8 | n/d | 147.2 | N/D | 147.9 |
| 10% (°C) | 165.0 | 165.3 | 167 | 167.6 | 165 | 168.3 |
| 50% (°C) | 228 | 229.7 | 237.5 | 241.1 | 228 | 231.3 |
| 90% (°C) | 273 | 274.3 | 274 | 275.9 | 273 | 274.5 |
| End Point (°C) | 280.5 | 278.6 | 281 | 279 | 280.5 | 278.5 |
| Residue % Volume | 1.2 | 1.5 | 1.2 | 1.5 | 1.2 | 1.5 |
| Loss % Volume | 0.9 | 1 | 0.9 | 1.6 | 0.9 | 1.1 |
| ASTM D5453 Sulfur, ppm | 0.45 | N/D | 0.37 | N/D | 0.45 | N/D |
| ASTM D2622 Sulfur, ppm | N/D | <10 | N/D | <10 | N/D | <10 |
| ASTM D445 Viscosity @ -20°C cST | 6.01 | 6.01 | 6.7 | 6.7 | 6.01 | 6.01 |
| ASTM D445 Viscosity @ 40°C cST | 1.54 | 1.55 | 1.63 | 1.64 | 1.54 | 1.55 |
| ASTM D4052 Density @ 15°C | 762.8 | 765 | 764.8 | 766 | 762.8 | 764 |
| ASTM D93 Flash Point °C (F°) | 44.5 (112) | 45 (113) | 46.5 (115.7) | 47 (116.5) | 44.5 (112) | 45.5 (113.9) |

**Table 5. Comparison of Analyses Results of 2nd Shipment of HRJ-8 CAF- 7815**

| HRJ-8 CAF-7815 Comparison Analyses (2nd Shipment, 16,382 gallons, 25, 26,& 27 January 2011) | | | | | | |
|---|---|---|---|---|---|---|
| **Properties** | **Results, COA Tanker 1** | **Results, TFLRF Lab** | **Results, COA Tanker 2** | **Results, TFLRF Lab** | **Results, COA Tanker 3** | **Results, TFLRF Lab** |
| ASTM D86 Distillation | | | | | | |
| IPB (°C) | n/d | 138.6 | n/d | 133.3 | n/d | 137.4 |
| 10% (°C) | 166.0 | 163.6 | 165 | 164.6 | 165 | 164.1 |
| 50% (°C) | 226 | 225.4 | 225.5 | 224.8 | 222.5 | 224.8 |
| 90% (°C) | 272.5 | 274.6 | 273.5 | 274.9 | 273.5 | 274.7 |
| End Point (°C) | 281 | 279.5 | 282 | 279.8 | 282 | 279.6 |
| Residue % Volume | 1.0 | 1.5 | 1.4 | 1.5 | 1.4 | 1.5 |
| Loss % Volume | 0.9 | 1 | 0.6 | 1.2 | 0.6 | 1.2 |
| ASTM D5453 Sulfur, ppm | <.05 | N/D | <.05 | N/D | <.05 | N/D |
| ASTM D2622 Sulfur, ppm | N/D | <10 | N/D | <10 | N/D | <10 |
| ASTM D445 Viscosity @ -20°C cST | 6.0 | 5.86 | 6.0 | 5.83 | 6.0 | 5.81 |
| ASTM D445 Viscosity @ 40°C cST | 1.55 | 1.52 | 1.56 | 1.54 | 1.55 | 1.51 |
| ASTM D4052 Density @ 15°C | 761.3 | 761.6 | 761.6 | 766 | 761.3 | 761.5 |
| ASTM D93 Flash Point °C (F°) | 44.5 (112) | 46 (114.8) | 44.5 (112) | 46.5 (115.7) | 44.5 (112) | 47 (116.6) |

**Table 6. Analyses of HRJ-8 Shipments Received at TFLRF and HRJ-8/JP-8 Blend Shipped to TARDEC**

| Property | Method | Units | HRJ-8 Received Oct 2010 Batch | HRJ-8 Received Jan 2011 Batch | HRJ-8/JP-8 Blended From Oct 2010 Batch |
|---|---|---|---|---|---|
| | | | | | |
| Color, Saybolt | ASTM D156 | Referee | 28 | 30 | 27 |
| Total Acid Number | ASTM D3242 | mg KOH/g | 0.005 | 0.002 | 0.007 |
| Hydrocarbons by FIA | ASTM D1319 | Vol% | | | |
| Aromatics | | | 0.5 | 0.6 | 10.7 |
| Olefins | | | 0.6 | 0.8 | 0.7 |
| Saturates | | | 98.9 | 98.6 | 88.6 |
| Sulfur, total | ASTM D2622 | Wt % | <0.001 | <0.001 | <0.001 |
| Sulfur, mercaptan | ASTM D3227 | Mass % | <0.0003 | <0.0003 | <0.0003 |
| Distillation | ASTM D86 | °C @ vol% evap. | | | |
| | | IBP | 145.1 | 133.8 | 156.2 |
| | | 5 | 162.6 | 160.2 | 170 |
| | | 10 | 166.5 | 163.3 | 170.2 |
| | | 15 | 173.2 | 169.4 | 174.6 |
| | | 20 | 180.6 | 176.8 | 177.1 |
| | | 30 | 197.1 | 191.3 | 183.2 |
| | | 40 | 214.9 | 208.4 | 190.3 |
| | | 50 | 232.8 | 225.2 | 198 |
| | | 60 | 247.8 | 241.2 | 208.3 |
| | | 70 | 260.2 | 255.4 | 222.1 |
| | | 80 | 269.1 | 266.6 | 243.1 |
| | | 90 | 274.9 | 274.7 | 267.9 |
| | | 95 | 277.7 | 278.5 | 275.4 |
| | | FBP | 278.6 | 279.9 | 277.2 |
| | | Residue vol% | 1.5 | 1.5 | 1.4 |
| | | Loss vol% | 1.3 | 1.1 | 1.5 |
| Flash point | ASTM D93 | °C | 46.5 | 45.5 | 48.5 |
| Density @ 15°C | ASTM D4052 | g/mL | 0.764 | 0.761 | 0.782 |
| Gravity, API @60°F | | | 53.71 | 54.44 | 49.45 |
| Freezing point | ASTM D2386 | °C | -52.2 | -58 | -65 |
| Viscosity at -20°C | ASTM D445 | $mm^2/s$ | 6.18 | 5.86 | 4.35 |
| Hydrogen | ASTM D3701 | Mass% | 15.25 | 15.33 | 14.5 |
| Heat of combustion | ASTM D4809 | MJ/kg | | | |
| Net | | | 45.29 | 45.42 | 44.82 |
| Gross | | | 47.21 | 47.33 | 47.99 |
| Hydrogen content | ASTM D5291 | Mass% | 15.25 | 15.23 | 14.33 |
| Smoke point | ASTM D1322 | mm | 34.7 | 27.7 | 33.3 |
| Naphthalenes | ASTM D1840 | Volume % | 0 | 0 | 0.16 |
| Calculated Cetane index | ASTM D976 | | 71.8 | 70.6 | 51 |
| Copper strip corrosion, 2hr @100°C (212°F) | ASTM D130 | | 1A | 1A | 1A |
| JFTOT @ 260°C | ASTM D3241 | mm/mg | 1 | 0 | 0 |
| Existent gum | ASTM D381 | mg/100mL | <0.5 | <0.5 | 0.6 |
| Particulate matter | ASTM D5452 | mg /L | 0.5 | 0 | 0.4 |
| Filtration time | | minutes | 6.12 | 9 | 6.1 |
| Water reaction interface rating | ASTM D1094 | mL | 1 | 1 | 1 |
| Water separation index | ASTM D3948 | Rating | 48 | 98 | 33 |
| FSII | ASTM D5006 | Vol% | 0 | 0 | 0.08 |
| Electrical conductivity | ASTM D2624 | pS/m | 163 | 193 | 333 |

**Table 6. Analyses of HRJ-8 Shipments Received at TFLRF and HRJ-8/JP-8 Blend Shipped to TARDEC (continued)**

| Additional Analyses Required by WD004 Revision 3 | | | | | |
|---|---|---|---|---|---|
| **Property** | **Method** | **Units** | **HRJ-8 Received Oct 2010 Batch** | **HRJ-8 Received Jan 2011 Batch** | **HRJ-8/JP-8 Blended From Oct 2010 Batch** |
| Hydrocarbon Types by | ASTM D2425 | Wt% | -- | -- | Not Required |
| Mass Spectrometry | | | -- | -- | -- |
| Paraffin | | | 94.5 | 93.7 | -- |
| Monocycloparaffins | | | 5.5 | 6.1 | -- |
| Dicycloparaffins | | | 0 | 0.2 | -- |
| Triycloparaffins | | | 0 | 0.0 | -- |
| Napthalene | | | 5.5 | 6.3 | -- |
| Saturates | | | 100 | 100 | -- |
| Aromatics | | | -- | | -- |
| Alkybenzenes | | | 0.0 | 0.0 | -- |
| Idans/tetralins | | | 0.0 | 0.0 | -- |
| Idenes | | | 0.0 | 0.0 | -- |
| Naphthalene | | | 0.0 | 0.0 | -- |
| Napthalenes, alkyl | | | 0.0 | 0.0 | -- |
| Acenapthenes | | | 0.0 | 0.0 | -- |
| Acenaphtylenes | | | 0.0 | 0.0 | -- |
| Tricyclic aromatics | | | 0.0 | 0.0 | |
| Carbon Hydrogen | ASTM D5291 | Mass% | -- | -- | -- |
| Carbon | | | 84.39 | 84.52 | 85.11 |
| Hydrogen | | | 15.25 | 15.23 | 14.33 |
| Water Coulometric-KF | ASTM D6304 | mg/kg | 16 | 160 | Not Required |
| Elements | ASTM D7111 | ppb | -- | -- | Not Required |
| Al | | | 321 | 252 | -- |
| Ba | | | >100 | >100 | -- |
| Ca | | | >100 | >100 | -- |
| Cr | | | >100 | >100 | -- |
| Cu | | | >100 | >100 | -- |
| Fe | | | >100 | >100 | -- |
| Li | | | 128 | 171 | -- |
| Pb | | | >100 | >100 | -- |
| Mg | | | >100 | >100 | -- |
| Mn | | | >100 | >100 | -- |
| Mo | | | >100 | >100 | -- |
| Ni | | | >100 | >100 | -- |
| K | | | >1 | >1 | -- |
| Na | | | >1 | >1.1 | -- |
| Si | | | >100 | >100 | -- |
| Ag | | | >100 | >100 | -- |
| Ti | | | >100 | >100 | -- |
| V | | | >100 | >100 | -- |
| Zn | | | >100 | >100 | -- |
| Derived Cetane Number | ASTM D6890 | | 58.06 | 57.76 | 47.59 |
| Viscosity at 40°C | ASTM D445 | $mm^2/s$ | 1.58 | 1.5 | 1.3 |
| BOCLE | ASTM D5001 | mm | 0.69 | 0.94 | 0.47 |
| Bulk Modulus | | psi@30°C | 170743 | 169089 | 176317 |

In July 2011, TFLRF supplied TARDEC with 7000 gallons of a 50/50% blend of HRJ-8 (2nd shipment) and Jet A (with JP-8 additives). The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. Complete fuel analyses of the blend and the 2nd HRJ-8 shipment are presented in Table 7.

**Table 7. Analyses of HRJ-8 Shipment 2 Received at TFLRF & HRJ-8/JP-8 Blend Shipped to TARDEC**

| Property | Method | Units | HRJ-8 Received Jan 2011 Batch | HRJ-8/JP-8 Blended Jan 10 2011 Batch |
|---|---|---|---|---|
| Color, Saybolt | ASTM D156 | Referee | 30 | -2 |
| Total Acid Number | ASTM D3242 | mg/KOH/gm | 0.002 | 0.006 |
| Hydrocarbons by FIA | ASTM D1319 | Vol% | | |
| Aromatics | | | 0.6 | 11.4 |
| Olefins | | | 0.8 | 0.6 |
| Saturates | | | 98.6 | 88 |
| Sulfur, total | ASTM D2622 | Wt % | <0.001 | 0.0137 |
| Sulfur, mercaptan | ASTM D3227 | Mass % | <0.0003 | <0.0003 |
| Distillation | ASTM D86 | °C @ vol% evap. | | |
| | | IBP | 133.8 | 160.3 |
| | | 5 | 160.2 | 172 |
| | | 10 | 163.3 | 174.7 |
| | | 15 | 169.4 | 178.2 |
| | | 20 | 176.8 | 181.5 |
| | | 30 | 191.3 | 188.1 |
| | | 40 | 208.4 | 195 |
| | | 50 | 225.2 | 203.6 |
| | | 60 | 241.2 | 212.3 |
| | | 70 | 255.4 | 223 |
| | | 80 | 266.6 | 238 |
| | | 90 | 274.7 | 258 |
| | | 95 | 278.5 | 270 |
| | | FBP | 279.9 | 277.7 |
| | | Residue vol% | 1.5 | 1.3 |
| | | Loss vol% | 1.1 | 0.5 |
| Flash point | ASTM D93 | °C | 45.5 | 48.5 |
| Density @ 15°C | ASTM D4052 | g/mL | 0.761 | 0.7752 |
| Gravity, API @ 60°F | | | 54.44 | 49.45 |
| Freezing point | ASTM D2386 | °C | -58 | -62 |
| Viscosity at -20°C | ASTM D445 | mm²/s | 5.86 | 4.54 |
| Hydrogen | ASTM D3701 | Mass% | 15.33 | 14.4 |
| Heat of combustion | ASTM D4809 | MJ/kg | | |
| Net | | | 45.42 | 43.44 |
| Gross | | | 47.33 | 46.5 |
| Hydrogen content | ASTM D5291 | Mass% | 15.23 | 14.4 |
| Smoke point | ASTM D1322 | mm | 27.7 | 33.3 |
| Naphthalenes | ASTM D1840 | Volume % | 0 | 0.39 |
| Calculated Cetane index | ASTM D976 | | 70.6 | 51 |
| Copper strip corrosion, 2hr @100°C (212°F) | ASTM D130 | | 1A | 1A |
| JFTOT @ 260°C | ASTM D3241 | mm/mg | 0 | 1 |
| Existent gum | ASTM D381 | mg/100mL | <0.5 | 7 |
| Particulate matter | ASTM D5452 | mg /L | 0 | 1.6 |

**Table 7. Analyses of HRJ-8 Shipment 2 Received at TFLRF & HRJ-8/JP-8 Blend Shipped to TARDEC (continued)**

| Property | Method | Units | HRJ-8 Received Jan 2011 Batch | HRJ-8/JP-8 Blended Jan 10 2011 Batch |
|---|---|---|---|---|
| | | | | |
| Filtration time | | minutes | 9 | 4.44 |
| Water reaction interface rating | ASTM D1094 | mL | 1 | 1 |
| Water separation index | ASTM D3948 | Rating | 98 | 70 |
| FSII | ASTM D5006 | Vol% | 0 | 23 |
| Electrical conductivity | ASTM D2624 | pS/m | 193 | 0 |
| Carbon Hydrogen | ASTM D5291 | Mass% | -- | -- |
| Carbon | | | 84.52 | 85.5 |
| Hydrogen | | | 15.23 | 14.4 |
| Water Coulometric-KF | ASTM D6304 | mg/kg | 160 | Not Required |
| Derived Cetane Number (IQT) | ASTM D6890 | | 57.76 | 50.58 |
| Viscosity at 40°C | ASTM D445 | $mm^2/s$ | 1.5 | 1.34 |
| BOCLE | ASTM D5001 | mm | 0.94 | 0.61 |
| Bulk Modulus | | psi@30°C | 169089 | 178673 |

In February 2012, TFLRF supplied TARDEC with 6,700 gallons of 50/50%v blend of HRJ-8 (comingled 1st and 2nd shipments) and Jet A with JP-8 additives. The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. The analyses of this blend are presented in Table 8.

**Table 8. HRJ-8/JP-8 Blend CL12-3384**

| Property | Units | Method | Min | Max | Results |
|---|---|---|---|---|---|
| Color, Saybolt | Referee | ASTM D156 | | | 8 |
| Total Acid Number | mg/KOH/gm | ASTM D3242 | | 0.015 | 0.012 |
| Aromatics | Volume % | ASTM D1319 | | 25 | 8 |
| Sulfur, total | Mass % | ASTM D2622 | | 0.30 | 0.014 |
| Sulfur, mercaptan | Mass % | ASTM D3227 | | 0.002 | <0.0003 |
| Distillation<br>IBP<br>10<br>20<br>50<br>90<br>FBP<br>Residue<br>Loss | °C @ vol% evap. | ASTM D86 | <br><br>157<br><br>168<br>183<br><br><br><br> | <br><br>205<br><br>229<br>262<br>300<br>1.5<br>1.5 | <br>154<br>171.1<br>178.7<br>205.3<br>263.1<br>278.9<br>1.2<br>0.7 |
| Flash point | °C | ASTM D93 | 38 | 68 | 39.5 |
| Density @ 15°C | kg/L | ASTM D4052 | 0.775 | 0.840 | 0.778 |
| Viscosity at -20°C | mm²/s | ASTM D445 | | 8.0 | 4.67 |
| Viscosity at 40°C | mm²/s | ASTM D445 | | | 1.3 |
| Heat of combustion<br>Net<br>Gross | MJ/kg | ASTM D4809 | 42.8 | <br><br> | <br>42.5<br>39.7 |
| Hydrogen content | Mass% | ASTM D3701 | 13.4 | | 14.64 |
| Smoke point | Volume % | ASTM D1322 | 25 | | 24 |
| Naphthalenes | Volume % | ASTM D1840 | | 3.0 | 0.51 |
| Calculated cetane index | | ASTM D976 | Report | | 55.6 |
| Copper strip corrosion, 2hr @ 100°C (212°F) | | ASTM D130 | | No. 1 | 1A |
| Hydrocarbons by FIA<br>Aromatics<br>Olefins<br>Saturates | Volume % | ASTM D1319 | | | -<br>8<br>2.9<br>89.1 |
| Filtration Time | minutes | | | 15 | 7 |
| Water reaction interface rating | mL | ASTM D1094 | | 1 | 1 |
| Water separation index | Rating | ASTM D3948 | 70 | | 0 |
| Fuel system icing inhibitor | Volume % | ASTM D5006 | 0.10 | 0.15 | 0.14 |
| Fuel electrical conductivity | pS/m | ASTM D2624 | 150 | 600 | 540 |
| Derived Cetane Number (IQT) | | ASTM D6890 | | | 54.68 |
| Bulk Modulus @ 30C | psi | ASTM D6793 | | | 175,144 |
| BOCLE | mm | ASTM D5001 | | | 0.47 |
| Specific Energy | MJ/kg | ASTM D3338 | | | 43.7 |
| Carbon/Hydrogen | Mass % | ASTM D5291 | | | 85.22/14.64 |
| Freeze Point (Auto) | °C | ASTM D5972 | | | -51.6 |
| HFRR | g | ASTM D6078 | | | 2850 |
| SBOCLE | mm | ASTM D6079 | | | 72.5 |
| Sulfur, Energy Dispersive | ppm | ASTM D4294 | | | >100 |

In June 2012, TFLRF supplied TARDEC with 6,500 gallons of 50/50%v blend of HRJ-8 (comingled all shipments) and JP-8. The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. The brief analyses of this blend are presented in Table 9.

**Table 9. HRJ-8/JP-8 Blend**

| Property | Units | Method | Min | Max | Result |
|---|---|---|---|---|---|
| Density @ 15°C | kg/L | ASTM D4052 | 0.775 | 0.840 | 0.772 |
| Hydrocarbons by FIA | Vol% | ASTM D1319 | | | |
| Aromatics | | | | | 6 |
| Olefins | | | | | 1.5 |
| Saturates | | | | | 92.5 |
| Viscosity at 40°C | $mm^2/s$ | ASTM D445 | | | 1.3 |
| Distillation | °C @ vol% evap. | ASTM D86 | | | |
| | IBP | | | Report | 149.6 |
| | 10 | | 157 | 205 | 165.1 |
| | 20 | | | | 173.3 |
| | 50 | | 168 | 229 | 202.9 |
| | 90 | | 183 | 262 | 264.1 |
| | FBP | | | 300 | 279.6 |
| | Recovered | | | | 98.6 |
| | Residue | | | 1.5 | 1.1 |
| | Loss | | | 1.5 | 0.3 |
| BOCLE | mm | ASTM D5001 | | | 0.53 |
| SBOCLE | g | ASTM D6078 | | | 2150 |
| HFRR | mm | ASTM D6079 | | | 0.763 |

In February 2012, TFLRF received 5,000 gallons of HRJ-5 from Centuri Technologies, LP. The manufacturer supplied Certificate of Analysis is included in Appendix A. In June 2012, TFLRF supplied Camp Grayling, MI with 10,000 gallons of 50/50%v blend of HRJ-5 and purchased JP-8 . The overall blend was adjusted to contain the maximum treat rate of 22.5 ppm of DCI-4A per MIL-PRF-25017. The analyses of this blend are presented in Table 10.

**Table 10. Properties of Fuel Blend Supplied to Camp Grayling, MI**

| HRJ-5/JP-8 Fuel Properties, Camp Grayling Shipment | | | | | |
|---|---|---|---|---|---|
| **Property** | **Units** | **Method** | **Min** | **Max** | **Results** |
| Color, Saybolt | Referee | ASTM D156 | | | 22 |
| Total Acid Number | mg/KOH/gm | ASTM D3242 | | 0.015 | 0.11 |
| Aromatics | Volume % | ASTM D1319 | | 25 | 6 |
| Sulfur, total | Mass % | ASTM D2622 | | 0.30 | 0.014 |
| Sulfur, mercaptan | Mass % | ASTM D3227 | | 0.002 | <0.0003 |
| Distillation | °C @ vol% evap.<br>IBP<br>10<br>20<br>50<br>90<br>FBP<br>Residue<br>Loss | ASTM D86 | <br><br>157<br><br>168<br>183<br><br><br> | <br><br>205<br><br>229<br>262<br>300<br>1.5<br>1.5 | <br>159.6<br>176.4<br>184<br>209.9<br>262.9<br>275.3<br>1.2<br>0.1 |
| Flash point | °C | ASTM D56 | 38 | 68 | 44 |
| Density @ 15°C | kg/L | ASTM D4052 | 0.775 | 0.840 | 0.7736 |
| Freezing point | °C | ASTM D2386 | | -47 | -54 |
| Viscosity at -20°C | mm²/s | ASTM D445 | | 8.0 | 5.05 |
| Viscosity at 40°C | mm²/s | ASTM D445 | | | 1.4 |
| Heat of combustion<br>Net<br>Gross | MJ/kg | ASTM D4809 | 42.8 | | <br>43.842<br>45.310 |
| Hydrogen content | Mass% | ASTM D3701 | 13.4 | | 14.76 |
| Smoke point | Volume % | ASTM D1322 | 25 | | 30.2 |
| Naphthalenes | Volume % | ASTM D1840 | | 3.0 | 0.036 |
| Calculated cetane index | | ASTM D976 | Report | | 59.6 |
| Copper strip corrosion, 2hr @ 100°C (212°F) | | ASTM D130 | | No. 1 | 1A |
| Thermal stability pressure drop,<br>heater tube deposit, visual rating | Mm Hg | ASTM D3241 | | 25<br><3 | <br><1 |
| Existent gum | mg/100mL | ASTM D381 | | 7 | 0.5 |
| Particulate matter | mg/L | ASTM D5452 | | 1 | 0.6 |
| Hydrocarbons by FIA<br>Aromatics<br>Olefins<br>Saturates | Vol% | ASTM D1319 | | | -<br>6<br>1.6<br>92.4 |
| Filtration time | minutes | | | 15 | 7 |
| Water reaction interface rating | mL | ASTM D1094 | | 1 | 1 |
| Water separation index | Rating | ASTM D3948 | 70 | | 85 |
| Fuel system icing inhibitor | Volume % | ASTM D5006 | 0.10 | 0.15 | 0.6 |
| Fuel electrical conductivity | pS/m | ASTM D2624 | | | 20 |
| Derived Cetane Number (IQT) | | ASTM D6890 | | | 54.68 |
| Bulk Modulus @ 30C | | ASTM D6793 | | | 172,299 |
| BOCLE | mm | ASTM D5001 | | | 0.56 |

### 3.4 HRJ-8 LOSS

In August of 2011, a fuel handling error resulted in the loss of approximately 3500 gallons of HRJ-8. TARDEC's Project Technical Monitor, TACOM's contracting, and San Antonio DCMA were informed of the event. A Loss, Theft, Damage, Destruction (LTDD) report was submitted to TACOM contracting. The San Antonio DCMA, government property administrator visited SwRI to investigate the incident and confirm that corrective actions were put in place. On October 25th, 2011 SwRI received the results of this investigation. The government found that the fuel loss was not the result of willful misconduct or lack of good faith on the part of the contractor's managerial personnel. Therefore, SwRI was relieved for the loss/contamination amount. In February 2012, an additional 4,500 gallons of HRJ-8 were supplied by DLA Energy and added to the comingled HRJ-8 at TFLRF. The Certificate of Analysis for this shipment of HRJ-8 is included in Appendix B.

### 3.5 FUEL PICKUP FROM WPAFB

TFLRF made arrangements to transport 1,000 gallons of FT SPK AF7618 from WPAFB. Selected analyses were requested on a sample obtained from the tanker that delivered the 1,000 gallons of FT SPK from WPAFB. Results were compared with findings obtained at WPAFB laboratory to insure that fuel properties had not changed significantly. TFLRF analyses results indicated that the fuel received had a slightly lower flash point and IBP. Other properties were as expected. Results of Comparison analyses are presented below in Table 11.

**Table 11. Results of Comparison Analyses**

| WPAFB FT SPK CAF-7618 Comparison Analyses | | |
|---|---|---|
| **Properties** | **Results, WPAFB Lab** | **Results, TFLRF Lab** |
| ASTM D86 Distillation | | |
| IPB (°C) | 156 | 149 |
| 10% (°C) | 162 | 161 |
| 20% (°C) | 164 | 164 |
| 50% (°C) | 169 | 169 |
| 90% (°C) | 185 | 185 |
| End Point (°C) | 200 | 202 |
| Residue % Volume | 1 | 1 |
| Loss % Volume | 0.7 | 1 |
| ASTM D2622 Sulfur, ppm | 3.00 | <10 |
| ASTM D445 Viscosity @ -20°C cST | 2.6 | 2.5 |
| ASTM D4052 Density @ 15°C | 0.737 | 0.737 |
| ASTM D93 Flash Point °C (F°) | 46/(115) | 42/(108) |

This FT SPK was used in various alternative fuels projects at TFLRF.

## 4.0 SUMMARY AND CONCLUSIONS

TFLRF completed fuel blending and delivered synthetic fuels blends as requested by TARDEC during the period June 2009 through January 2013.

## 5.0 REFERENCES

Military Specification, MIL-DTL-83133E, “Turbine Fuels, Aviation, Kerosene Types, NATO F-34 (JP-8), NATO F-35, and JP-8+100”

Qualified Products List of Products Qualified Under Performance Specification MIL-PRF-25017 Inhibitor, Corrosion/Lubricity Improver, Fuel Soluble

# APPENDIX A

# HRJ-5 Certificate of Analysis

# CENTAURI Technologies, LP

## HRJ-5 Certificate of Analysis for UOP, LLC.

AF-8183
TK-208B
2-28-12

| | | |
|---|---|---|
| **Material Name** | : | Hydro-treated Renewable Jet, "HRJ5" – Camelina |
| **Customer Name** | : | UOP, LLC |
| **Lot Number** | : | Lot No. 1211-C10818/19/20 (*from R/C TILX 250190*) |
| **Shipping Date** | : | 28-February-2012 |
| **Container Identification** | : | Suttles DANA T/T No. 1426 |
| **Sample Identification** | : | S-20212-6180 |
| **Approximate Shipping Load** | : | 30,802 lbs ( 4,822 gallons ) *( subject to correction )* |
| **Customer Order Number** | : | 4500329445 |
| **Bill of Lading Number** | : | SP06000000922 |

| Measured Properties | Units | Test Method | Specification Minimum | Specification Maximum | Measured Value | Measured By | Reference Document |
|---|---|---|---|---|---|---|---|
| Flash Point | °C | D 93 | 60 | | *62.5* | Dixie Services | No. 139812 |
| Density at 15°C | kg/L | D 1298 | 0.760 | 0.845 | *0.7660* | Dixie Services | No. 139812 |
| Total Water | ppm | D 6304 | | 75 | *28* | Dixie Services | No. 139812 |
| Particulate | mg/L | D 5452 | | 1.0 | *0.12* | Dixie Services | No. 139812 |
| *Filtration Time* | minutes | | | 15 | *6* | Dixie Services | No. 139812 |
| Kinematic Viscosity at -20°C | $mm^2/sec$ | D 445 | | 8.5 | *7.448* | Dixie Services | No. 139812 |
| Cetane Number | | D 613 | 40 | | *62.3* | Dixie Services | No. 139812 |
| Distillation | | | | | | | |
| *IBP* | °C | D 86 | Report | | *173.5* | Dixie Services | No. 139812 |
| *10%, (T10)* | | | | 205 | *190.0* | Dixie Services | No. 139812 |
| *50%, (T50)* | | | Report | | *230.5* | Dixie Services | No. 139812 |
| *90%, (T90)* | | | Report | | *270.5* | Dixie Services | No. 139812 |
| *Final Boiling Point* | | | | 300 | *276.5* | Dixie Services | No. 139812 |
| *Residue* | vol % | | | 1.5 | *1.5* | Dixie Services | No. 139812 |
| *Loss* | | | | 1.5 | *0.5* | Dixie Services | No. 139812 |
| *T90-T10* | °C | | 25 | | *80.5* | Dixie Services | No. 139812 |
| Copper Strip Corrosion at 100°C | | D 130 | | No. 1 | *1b* | Dixie Services | No. 139812 |

# CENTAURI Technologies, LP

## HRJ-5 Certificate of Analysis for UOP, LLC.

| Measured Properties | Units | Test Method | Specification | | Measured Value | Measured By | Reference Document |
|---|---|---|---|---|---|---|---|
| | | | Minimum | Maximum | | | |
| Freezing Point | °C | D 2386 | | - 46 | *-53.0* | Dixie Services | No. 139812 |
| Hydrogen Content | mass % | D 7171 | 13.4 | | *15.24* | UOP, LLC | LIMS No. 260400721 |
| Heating Value | MJ / kg | D 4809 | 42.6 | | *43.935* | Dixie Services | No. 139812 |
| MSEP | | D 3948 | 85 | | *95* | Dixie Services | No. 139812 |
| Total Acid Number | mg KOH/g | D 3242 | | 0.015 | *0.004* | Dixie Services | No. 139812 |
| JFTOT at 280°C | | | | | | | |
| *Tube Deposit Rating* | visual | D 3241 | | 3 | *1* | Dixie Services | No. 139812 |
| *dP* | mm Hg | | | 25 | *0* | Dixie Services | No. 139812 |
| Additives | | | | | | | |
| *Antioxidant, AO-37* | ppm | P 487 | 17.2 | 24 | *20* | Calculated | |
| *Corrosion Inhibitor, DCI-4A* | | | 9 | 24 | *15* | Calculated | |
| Hydrocarbon Composition | | | | | | | |
| *Paraffins (n- and iso-)* | mass % | D 2425 | Balance | | *96* | UOP, LLC | UDRI Dec. 29, 2011 |
| *Cycloparaffins* | | | | 15 | *4* | UOP, LLC | UDRI Dec. 29, 2011 |
| *Total Aromatics* | | D 6379 | | 0.5 | *< 0.3* | UOP, LLC | UDRI Dec. 29, 2011 |
| Sulfur Content | ppm | D 5453 | | 15 | *< 0.05* | Dixie Services | No. 139812 |
| Nitrogen Content | ppm | D 4629 | | 10 | *< 0.10* | Dixie Services | No. 139812 |
| Metals *Ca, Cu, Fe, Mg, Mn, Ni, P, Pb, V, Zn* | ppm | D 7111 | | 0.5, total | *0.04* | Dixie Services | No. 139812 |
| Alkali Metals and Metalloids *B, Na, K, Si, Li* | ppm | D 7111 | | 1.0, total | *0.05* | Dixie Services | No. 139812 |

Hien T. Nguyen

UOP, LLC Technical Representative

***28-February-2012***

Date

# APPENDIX B

# Certificate of Analysis for HRJ-8, February 2012

# UOP LLC - A Honeywell Company
## Analysis Report

| | | |
|---|---|---|
| **Material Name** | : | Hydrotreated Renewable Jet, HR-J8 |
| **Customer Name** | : | DLA (Army) |
| **Centauri Lot Number** | : | 1211-C10825-26 |
| **Shipping Date** | : | 2012 FEB 14 |
| **Container Identification** | : | Trailer 1371 |
| **Sample Identification** | : | S-00212-6051 |
| **Estimated Shipping Load** | : | 4,522 gallons (estimated total load) |
| **Customer Order Number** | : | 0001-00 |
| **Bill of Lading Number** | : | SP06000000909 |

| Measured properties | Units | Test Method | Specification Minimum | Specification Maximun | Measured Value | Measured By | Reference Document |
|---|---|---|---|---|---|---|---|
| Total Acidity | mg KOH/g | D3242 | | 0.015 | 0.004 | Dixie Services | 139990R |
| Physical Distillation | | | | | | | |
| *10%, (T10)* | °C | D86 | | 205 | 157.5 | Dixie Services | 139990R |
| *50%, (T50)* | °C | | Report | | 208.0 | Dixie Services | 139990R |
| *90%, (T90)* | °C | | Report | | 273.0 | Dixie Services | 139990R |
| *Final Boiling Point* | °C | | | 300 | 281.5 | Dixie Services | 139990R |
| *Residue* | vol % | | | 1.5 | 1.5 | Dixie Services | 139990R |
| *Loss* | vol % | | | 1.5 | 0.5 | Dixie Services | 139990R |
| *T90-T10* | °C | | 22 | | 115.5 | Dixie Services | 139990R |
| Simulated Distillation - D86 correlated data | | | | | | | |
| *10%, (T10)* | °C | D2877 | Report | | 160.5 | Dixie Services | 139990R |
| *50%, (T50)* | °C | | Report | | 210.0 | Dixie Services | 139990R |
| *90%, (T90)* | °C | | Report | | 270.5 | Dixie Services | 139990R |
| *Final Boiling Point* | °C | | Report | | 284.0 | Dixie Services | 139990R |
| Flash Point | °C | D56 | 38 | 68 | 40.5 | Dixie Services | 139990R |
| Density | $kg/m^3$ | D4052 | 751 | 840 | 756.6 | Dixie Services | 139990R |
| Freezing Point | °C | D2386 | | -47 | -52.5 | Dixie Services | 139990R |

File: UOP-AR. 004

# UOP LLC - A Honeywell Company
## Analysis Report

| Measured properties | Units | Test Method | Specification Minimum | Specification Maximun | Measured Value | Measured By | Reference Document |
|---|---|---|---|---|---|---|---|
| Viscosity at -20°C | $mm^2/s$ | D445 | | 8.0 | 4.816 | Dixie Services | 139990R |
| Viscosity at +40°C | $mm^2/s$ | D445 | Report | | 1.335 | Dixie Services | 139990R |
| Net Heat of Combustion | MJ/kg | D4809 | 42.8 | | 43.946 | Dixie Services | 139990R |
| Cetane Number | | D613 | 40 | | 58.4 | Dixie Services | 139990R |
| JFTOT at 2.5h | | | | | | | |
| *Temperature* | °C | D3241 | 280 | | 280 | Dixie Services | 139990R |
| *Tube Deposit Rating* | visual | | | 3 | 1 | Dixie Services | 139990R |
| *dP* | mm Hg | | | 25 | 0.0 | Dixie Services | 139990R |
| Electrical Conductivity 23°C | pS/m | D2624 | 150 | 450 | 233 | Dixie Services | 139990R |
| Additives | | | | | | | |
| *Antioxidant, AO-37* | ppm | P487 | 17 | 24 | 20 | Calculated | |
| *Static Dissipator Stadis 450* | ppm | | | | 1 | Calculated | |
| *Corrosion Inhibitor DCI-4A* | ppm | | | | 15 | Calculated | |
| Hydrocarbon Composition | | | | | | | |
| *Paraffins (n- and Iso-)* | mass % | D2425 | Balance | | 96 | UDRI | Letter dated Dec 29, 2011 |
| *Cycloparaffins* | | | | 15 | 4 | UDRI | Letter dated Dec 29, 2011 |
| *Total Aromatics* | | | | 0.5 | <0.3 | UDRI | Letter dated Dec 29, 2011 |
| *Carbon and Hydrogen* | | D5291 | 99.0 | | 99.5 | Dixie Services | 139990R |
| Nitrogen Content | mg/kg | D4629 | | 5 | <0.10 | Dixie Services | 139990R |
| Water | mg/kg | D6304 | | 75 | 27 | Dixie Services | 139990R |
| Sulfur Content | mg/kg | D5453 | | 15 | <0.05 | Dixie Services | 139990R |
| Water Separation Index without SDA | | D3948 | 85 | | 99 | Dixie Services | 140140 |
| Particulate Matter | mg/L | D5452 | | 1.0 | 0.05 | Dixie Services | 139990R |
| Filtration time | min | | | 15 | 5 | Dixie Services | 139990R |
| Volume | L | | 3.79 | | 4.1 | Dixie Services | 139990R |
| Metals | mg/kg | D7111 | | | | Dixie Services | 139990R |

| Measured Values | Ca | Cu | Fe | Mg | Mn | Ni | P | Pb | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.1 total max | BDL<0.01 | BDL<0.01 | BDL<0.01 | BDL<0.01 | BDL<0.01 | BDL<0.01 | BDL<0.01 | 0.02 | BDL<0.01 | BDL<0.01 |

| Glass Metals | Na | K | Si | Li |
|---|---|---|---|---|
| report | 0.03 | BDL<0.01 | BDL<0.01 | 0.01 |

DWC/m
UOP LLC Technical Representative

2.14.12
Date

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